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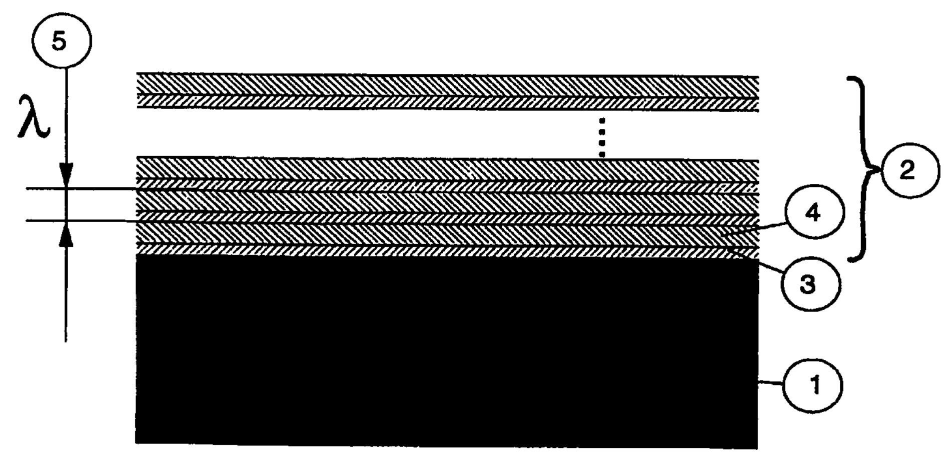
(54) Title: MULTILAYERED PVD COATED CUTTING TOOL



(57) Abstract

The present invention relates to a cutting tool comprising a body (1) of a sintered cemented carbide or cermet, ceramic or high speed steel on which, at least on the functioning parts of the surface of the body, a thin, adherent, hard and wear resistant coating (2) is applied. The coating comprises a laminar structure of refractory compounds in a polycrystalline, repetitive form: $(MLX/Al_2O_3)\lambda$ $(MLX/Al_2O_3)\lambda/$ $(MLX/Al_2O_3)\lambda/$ $(MLX/Al_2O_3)\lambda/...$ where the alternating sublayers consist of metal nitrides (or carbides) and crystalline alumina (4) of the alpha(α)- and/or the gamma(γ) phase, preferably of metal nitrides and crystalline alumina of the γ phase. The metal elements in the layers MLX (3) are selected from Ti, Nb, Hf, V, Ta, Mo, Zr, Cr, W and Al. The repeat period λ (5) is essentially constant through the entire multilayered structure, and larger than 3 nm but smaller than 100 nm. The total thickness of said multilayered coating is larger than 0.5 μm but smaller than 20 μm.

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Multilayered PVD coated cutting tool.

The present invention relates to a cutting tool for metal machining, having a substrate of cemented carbide, cermet, ceramics or high speed steel and, on the surface of said substrate, a hard and wear resistant refractory coating is deposited by Physical Vapor Deposition (PVD) or Chemical Vapor Deposition (CVD). The coating is adherently bonded to the substrate and is composed of a laminar, multilayered structure of metal nitrides or carbides in combination with alumina (Al_2O_3) with a repeat period of the individual layer thicknesses in the nanometer range (nm), and the metal elements of the nitride or carbide are selected from Ti, Nb, Hf, V, Ta, Mo, Zr, Cr, W or Al.

The process of depositing a thin refractory coating (1-20 µm) of materials like alumina, titanium carbide and/or titanium nitride onto e.g. a cemented carbide cutting tool is a well established technology and the tool life of the coated cutting tool, when used in metal machining, is considerably prolonged. The prolonged service life of the tool may under certain conditions extend up to several hundred percent greater than that of an uncoated tool. Said refractory coatings generally comprise either a single layer or a combination of layers. Modern commercial cutting tools are characterized by a plurality of layer combinations with double or multilayer structures. The total coating thickness varies between 1 and 20 micrometers (µm) and the thickness of the individual sublayers varies between a few microns and a few tenths of a micron.

The established technologies for depositing such coatings are CVD and PVD (see e.g. U.S. 4,619,866 and U.S. 4,346,123). PVD coated commercial cutting tools of cemented carbides or high speed steels usually have a

single coating of TiN, TiCN or TiAlN, but combinations thereof also exist.

There exist several PVD techniques capable of producing refractory thin films on cutting tools and the most established methods are ion plating, magnetron sputtering, arc discharge evaporation and IBAD (Ion Beam Assisted Deposition). Each method has its own merits and the intrinsic properties of the produced coating such as microstructure/grain size, hardness, state of stress, cohesion and adhesion to the underlying substrate may vary depending on the particular PVD method chosen. An improvement in the wear resistance or the edge integrity of a PVD coated cutting tool being used in a specific machining operation can thus be accomplished by optimizing one or several of the above mentioned properties.

Furthermore, new developments of the existing PVD techniques by i.e. introducing unbalanced magnetrons in reactive sputtering (S. Kadlec, J. Musil and W.-D. Munz in J. Vac. Sci. Techn. A8(3), (1990), 1318.) or applying a steered and/or filtered arc in cathodic arc deposition (H. Curtins in Surface and Coatings Technology, 76/77, (1995), 632 and K. Akari et al in Surface and Coatings Technology, 43/44, (1990), 312.) have resulted in a better control of the coating processes and a further improvement of the intrinsic properties of the coating material.

With the invention of the PVD bipolar pulsed DMS technique (Dual Magnetron Sputtering) which is disclosed in DD 252 205 and DE 195 18 779, a wide range of opportunities opened up for the deposition of insulating layers such as Al_2O_3. Furthermore, this method has made it possible to deposit crystalline Al_2O_3 layers at substrate temperatures in the range 500 to 800 °C.

Al_2O_3 exists in several different phases such as α(alpha), κ(kappa) and χ(chi) called the "α-series" with

hcp (hexagonal close packing) stacking of the oxygen atoms, and in γ(gamma), θ(theta), η(eta) and δ(delta) called the "γ-series" with fcc (face centered cubic) stacking of the oxygen atoms. The most often occurring Al_2O_3-phases in CVD coatings deposited on cemented carbides at conventional CVD temperatures, 1000°-1050 °C, are the stable α- and the metastable κ-phases, however, occasionally the metastable θ-phase has also been observed. According to DE 195 18 779, the DMS sputtering technique is capable of depositing and producing high-quality, well-adherent, crystalline α-Al_2O_3 thin films at substrate temperatures less than 800 °C. The "α-Al_2O_3" layers may partially also contain the gamma(γ) phase from the "γ-series" of the Al_2O_3 polymorphs. When compared to prior art plasma assisted deposition techniques such as PACVD as described in DE 49 09 975, the novel, pulsed DMS sputtering deposition method has the decisive, important advantage that no impurities such as halogen atoms, e.g. chlorine, are incorporated in the Al_2O_3 coating.

Conventional cutting tool material like cemented carbides consist of at least one hard metallic compound and a binder, usually cobalt (Co), where the grain size of the hard compound, e.g. tungsten carbide (WC), ranges in the 1-5 µm region. Recent developments have predicted improved tool properties in wear resistance, impact strength, hot hardness by applying tool materials based on ultrafine microstructures by using nanostructured WC-Co powders as raw materials (L.E. McCandlish, B.H. Kear and B.K. Kim, in Nanostructured Materials VOL. 1 pp. 119-124, 1992). Similar predictions have been made for ceramic tool materials by for instance applying silicon-nitride/carbide-based (Si_3N_4/SiC) nanocomposite ceramics and, for Al_2O_3-based ceramics, equivalent nanocomposites based on alumina.

With nanocomposite nitride/carbide and alumina hard coating materials, it is understood a multilayered coating where the thickness of each individual nitride (or carbide) and alumina layer is in the nanometer range between 3 and 100 nm, preferably between 3 and 20 nm. Since a certain periodicity or repeat period of the metal nitride/carbide and alumina layer sequence is involved, these nanoscaled, multilayer coatings have been given the generic name of "superlattice" films. With repeat period is meant the thickness of two adjacent metalnitride/carbide and alumina layers. Several of the binary nitride superlattice coatings with the metal element selected from Ti, Nb, V and Ta, grown on both single- and polycrystalline substrates have shown an enhanced hardness for a particular repeat period usually in the range 3-10 nm.

Fig 1 is a schematic representation of a cross-section taken through a coated body of the present invention.

According to the present invention there is provided a cutting tool for metal machining such as turning (threading and parting), milling and drilling comprising a body of a hard alloy of cemented carbide, cermet, ceramics or high speed steel, onto which a wear resistant, multilayered coating has been deposited. The shape of the cutting tool includes indexable inserts as well as shank type tools such as drills, end mills etc. More specifically, the coated tool comprises a substrate of sintered cemented carbide body or a cermet, preferably of at least one metal carbide in a metal binder phase, or a ceramic body. The substrate may also comprise a high speed steel alloy. Said substrate may also be precoated with a thin single- or multilayer of TiN, TiC, TiCN or TiAlN with a thickness in the micrometer range according to the prior art. The coating is applied onto

the entire body or at least the functioning surfaces thereof, e.g., the cutting edge, rake face, flank face or any other surface which participates in the metal cutting process.

The coated cutting tool according to the present invention exhibits improved wear resistance and toughness properties compared to prior art tools when used for machining steel or cast iron. The coating, which is adherently bonded to the substrate, comprises a laminar, multilayered structure of metal nitrides (or carbides) and crystalline alumina of the alpha(α)- and/or the gamma(γ) phase, preferably of metal nitrides and crystalline γ-Al_2O_3, has a thickness between 0.5 and 20 µm, preferably between 1 and 10 µm, most preferably between 2 and 6 µm. In the multilayered coating structure $(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/$......... the alternating layers are MLX and Al_2O_3 (see Fig. 1) where MLX comprises a metalnitride or a metalcarbide with the metal elements M and L selected from titanium (Ti), niobium (Nb), hafnium (Hf), vanadium (V), tantalum (Ta), molybdenum (Mo), zirconium (Zr), chromium (Cr), tungsten (W) or aluminium (Al). In said coating the repeat period λ in $(MLX/Al_2O_3)_\lambda$ is essentially constant throughout the entire multilayer structure. Furthermore, the repeat period is larger than 3 nm but smaller than 100 nm, preferably smaller than 50 nm, most preferably smaller than 25. The repeat period is meant the thickness of the layers MLX + Al_2O_3, i.e. two adjacent nanolayers. Preferred examples of the above described nanomultilayered coating structures are e.g. when M=L, TiN/Al_2O_3/TiN/Al_2O_3/TiN/ Al_2O_3/TiN/...... or when L$\neq$M, TiAlN/Al_2O_3/ TiAlN/ Al_2O_3/ TiAlN/ Al_2O_3/TiAlN/.......

Referring to Fig.1 there is shown a substrate 1 coated with a laminar, multilayered nitride/carbide and alumina coating 2 with the individual metal nitride (or

carbide) layers being MLX 3 and the individual alumina layers 4 and the repeat period λ 5, the thickness of the metalnitride/carbide layer and the alumina layer is essentially constant throughout the entire multilayer coating.

The laminar coatings above exhibit a columnar growth mode with no or very little porosity at the grain boundaries. The coatings also possess a substantial waviness in the sublayers which originates from the substrate surface roughness.

For a cutting tool used in metal machining, several advantages are provided by the present invention with nanostructured lamellae coatings deposited on substrates of hard, refractory materials such as cemented carbides, cermets and ceramics. In a lamellae coating of $(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/....$ on cemented carbides, the hardness of the coating is usually enhanced over individual single layers of MLX and Al_2O_3 with a layer thickness on a μm scale simultaneously as the intrinsic stress is smaller. The first observation, enhanced hardness in the coating, results in an increased abrasive wear resistance of the cutting edge while the second observation of less intrinsic stress in the coating, provides an increased capability of absorbing stresses exerted on the cutting edge during a machining operation. Furthermore, the invented coating gives the cutting edges of the tool an extremely smooth surface finish which, compared to prior art coated tools, results in an improved surface finish also of the workpiece being machined.

The laminar, nanostructured coatings according to the present invention can be deposited on a carbide, cermet, ceramic or high speed steel substrate either by CVD or PVD techniques, preferably by the PVD bipolar pulsed dual magnetron sputtering (DMS) technique, by

successively forming individual sublayers on the tool substrate at a substrate temperature of 450°-700 °C, preferably 550-650 °C, by switching on and off separate magnetron systems.

Claims

1. Cutting tool comprising a body of sintered cemented carbide or cermet, ceramics or high speed steel and on which at least on the functioning parts of the surface of the body, a thin, adherent, hard and wear resistant coating is applied, said coating characterized in comprising a laminar, multilayered structure of refractory compounds in polycrystalline, repetitive form,
$(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/(MLX/Al_2O_3)_\lambda/(MLX/\ Al_2O_3)_\lambda/\ldots\ldots$
where the alternating layers are MLX and Al_2O_3, and the MLX sublayers comprise a metal nitride or a metal carbide with the metal elements M and L selected from Ti, Nb, Hf, V, Ta, Mo, Zr, Cr, W and Al, and the Al_2O_3 sublayers consist of crystalline Al_2O_3 of the alpha(α)- and/or gamma(γ) phase, and in said coating the repeat period λ is essentially constant throughout the entire multilayered structure, and where the said repeat period λ is larger than 3 nm but smaller than 100 nm and that the total thickness of said multilayered coating is larger than 0.5 µm but smaller than 20 µm.

2. Cutting tool according to claim 1 characterized in that the crystalline Al_2O_3 sublayers consist of the gamma(γ) alumina phase

3. Cutting tool according to claim 2 characterized in that the MLX sublayers are composed of metal nitrides.

4. Cutting tool according to claim 3 characterized in that the sublayers of the metal nitrides consists of TiAlN and TiN, preferably TiAlN.

5. Cutting tool according to any of the preceding claims characterized in that the repeat period λ ranges from 3 to 50 nm, preferably from 3 to 25 nm.

6. Cutting tool according to any of the preceding claims characterized in that said coating has a total thickness of 1 to 10μm, preferably from 2 to 6 μm.

7. Cutting tool according to any of the preceding claims characterized in that said tool body is a cemented carbide or a cermet.

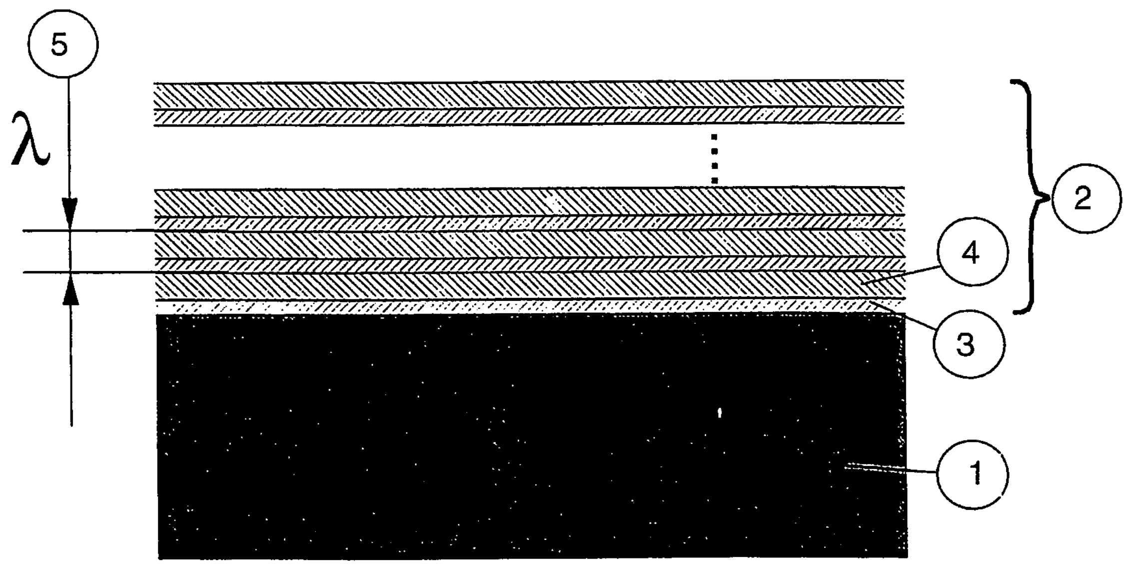

Figure 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/02268

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C23C 14/06, C23C 14/08, C23C 30/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C23C, B23B, C04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPIL,EDOC,JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2048960 A (FRIED KRUPP GESELLSCHAFT MIT BESCHRÄNKTER HAFTUNG), 17 December 1980 (17.12.80), page 1, line 32 - page 2, line 49, claims 1-9, abstract --	1-7
X	EP 0701982 A1 (SUMITOMO ELECTRIC INDUSTRIES, LIMITED), 20 March 1996 (20.03.96), page 2, line 1 - line 12; page 3, line 24 - line 48; page 5, line 36 - line 41, claims 1-4,8,11,13,17, 18 and abstract --	1-7
X	EP 0709483 A2 (SUMITOMO ELECTRIC INDUSTRIES, LTD.), 1 May 1996 (01.05.96), page 2, line 1 - line 21; page 7, line 10 - line 15, claims 1,5,33, abstract --	1-7

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0592986 A1 (SUMITOMO ELECTRIC INDUSTRIES, LIMITED), 20 April 1994 (20.04.94), page 2, line 32 - line 38; page 2, line 50 - page 3, line 53; page 4, line 30 - line 41, page 8, line 46 - line 58, claims 1,4,10, abstract --	4
A	Surface and Coatings Technology, Volume 82, 1996, O. Zywitzki et al, "Effect of the substrate temperature on the structure and properties of Al2O3 layers reactively deposited by pulsed magnetron sputtering", page 169 - page 175, see especially page 169 - page 171 --	2
A	US 4984940 A (WILLIAM A. BRYANT ET AL), 15 January 1991 (15.01.91), column 4, line 11 - column 5, line 23, figure 3, abstract -- --------	1-7

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Information on patent family members

02/03/99

International application No.
PCT/SE 98/02268

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